

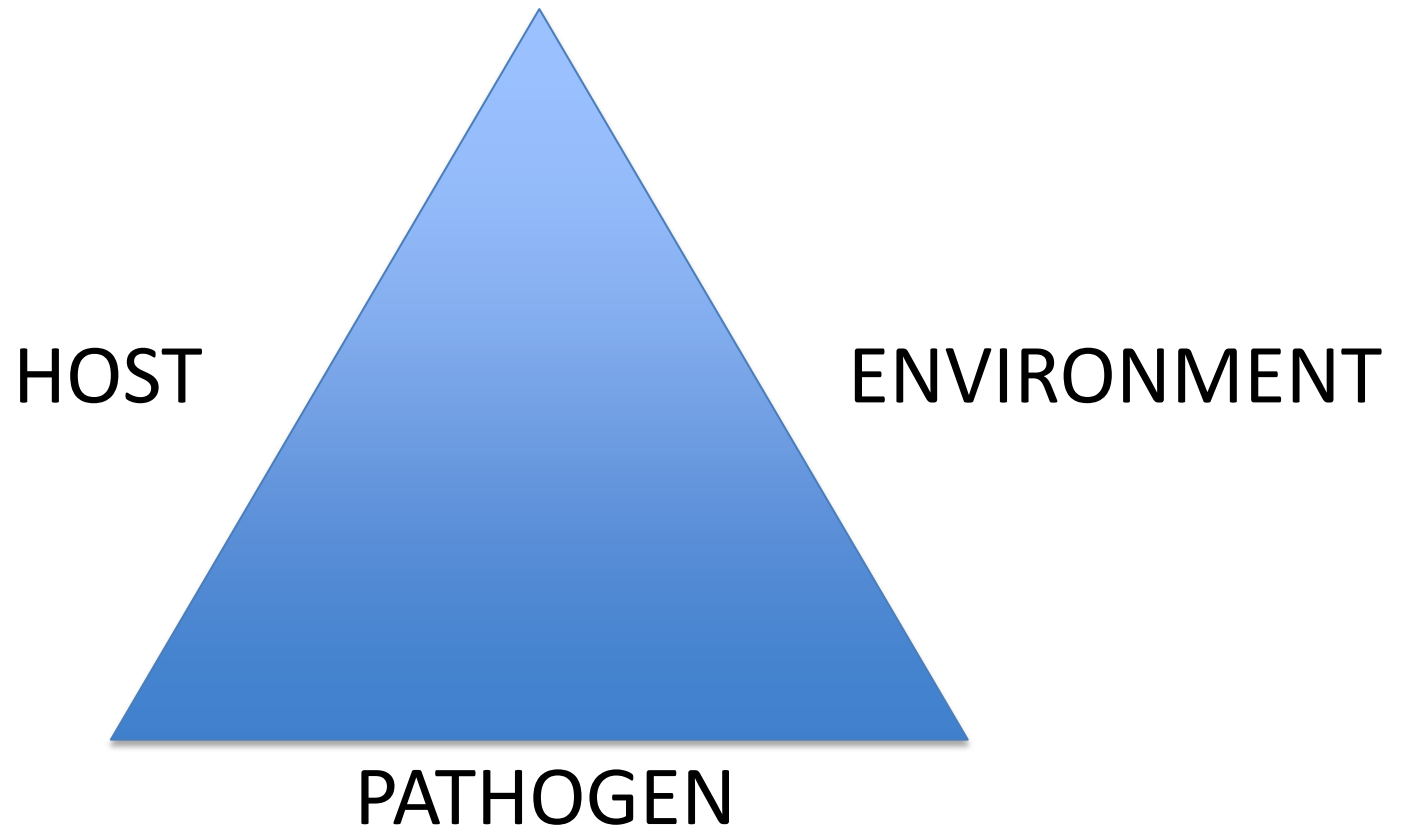
Plant Disease Management 101

**Tom Turini
UC ANR Advisor
Vegetable Crops, Fresno County**

University of California
Agriculture and Natural Resources

HEALTHY FOOD SYSTEMS • HEALTHY ENVIRONMENTS • HEALTHY COMMUNITIES • HEALTHY CALIFORNIANS

Plant Disease Triangle



University of California
Agriculture and Natural Resources

Disease Control in Organic Systems

- Knowledge of production system, major risk factors, biology of potentially important pathogens.

Disease Control in Organic Systems

- Knowledge of production system, major risk factors, biology of potentially important pathogens.
- Management strategies implemented before onset of widespread disease are the most effective.

Disease Control in Organic Systems


- Knowledge of production system, major risk factors, biology of potentially important pathogens.
- Management strategies implemented before onset of widespread disease are the most effective.
- Awareness of potential and limitations of management techniques.
 - Sanitation
 - Site/crop selection
 - Variety selection
 - Disease free planting material
 - Planting date
 - Soil preparation
 - Irrigation
 - Plant/canopy density
 - Monitoring
 - Maintenance of plant health
 - Physical means of pest control
 - Chemical or biological agents for disease control

Sanitation

- Avoid movement of pathogens from infested fields.
 - Soil on equipment for harvest or tillage



University of California
Agriculture and Natural Resources



Example of
Sanitation in
Management of
Soil-Borne Disease:
White Rot of Garlic
(and other Alliums)
Sclerotium cepivorum

Central San Joaquin Valley

More than 16,000 acres with
Sclerotium cepivorum

Sclerotia (resting structures)

- **Survive for decades**
- **Very few in soil can cause damage to Alliums**



Sanitation to limit spread of WR

- Cover trailers when infected garlic is harvested
- Clean planting material
- Inspection of garlic fields for white rot strikes/documentation of infested fields
- Special efforts to minimize risk of spread when infected garlic fields are harvested
- Clean equipment prior to movement from infested fields.

Sanitation

- Avoid movement of pathogens from infested fields.
 - Soil on equipment for harvest or tillage
- Vegetation management
 - Weed control
 - Complete incorporation of crop residue after harvest

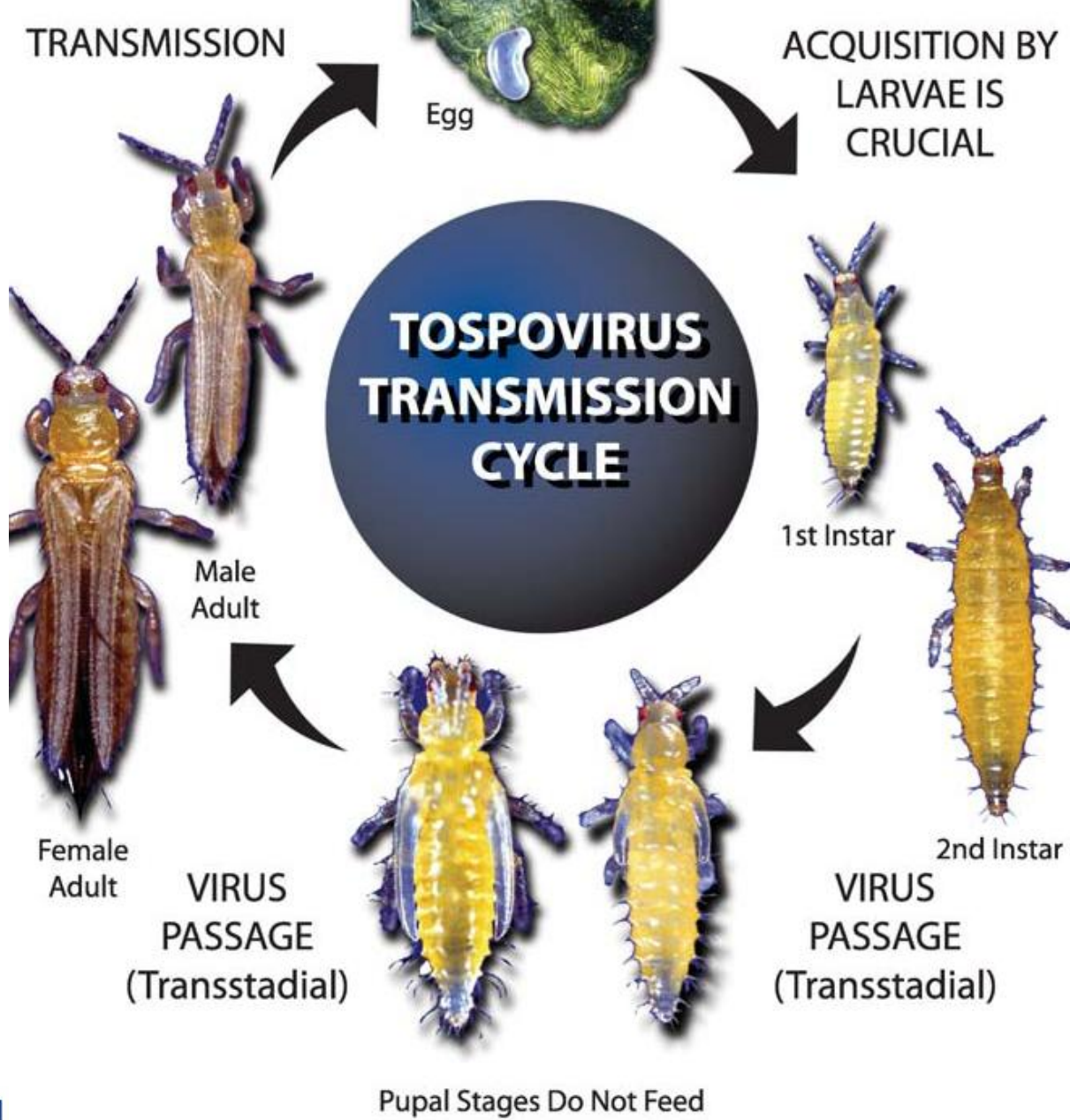


University of California
Agriculture and Natural Resources

Sanitation in Management of Virus Diseases: *Tomato spotted wilt virus*



University of California
Agriculture and Natural Resources



A. E. Whitfield,
 D. E. Ullman,
 and
 T. L. German.
 2005.
**TOSPOVIRUS-
 THRIPS
 INTERACTIONS.**
 Annu. Rev.
 Phytopathol.
 2005. 43:459–
 89

U
 Agriculture and Natural Resources

Weed Hosts of TSWV



Sowthistle with TSWV



Uncultivated Field on 22 Apr near tomatoes
(2% sowthistle and 7% prickly lettuce TSWV+)

- Prickly lettuce
- Sowthistle
- Malva
- Pineapple weed
- Field bindweed
- Common sunflower
- Black nightshade
- Jimson weed
- London Rocket
- Purslane
- Pigweed
- Lambsquarters
- Russian thistle
- Hairy fleabane

University of California
Agriculture and Natural Resources

Crop Hosts of TSWV



Very few questionably symptomatic plants tested have TSWV

- Beans
- Celery
- Lettuce
- Tomato
- Pepper
- Potato
- Eggplant
- Radicchio
- Spinach

University of California
Agriculture and Natural Resources

Sanitation for reduction of TSWV

- Incorporate residues of susceptible crops and weedy non-host crops immediately after harvest.
- Control susceptible weeds (such as sow thistle and prickly lettuce) on roadsides, and in crops such as almonds, pistachios, garlic and wheat.

Sanitation

- Avoid movement of pathogens from infested fields.
 - Soil on equipment for harvest or tillage
- Vegetation management
 - Weed control
 - Complete incorporation of crop residue after harvest
- Avoid cull piles, which may serve as sources of inoculum.



University of California
Agriculture and Natural Resources

Onion cull piles as source of inoculum



Onion cull piles



Downy mildew



University of California
Agriculture and Natural Resources



Iris yellow spot virus

Site/Crop Selection

- Avoid planting susceptible crops near sources of diseases or consider management strategies.

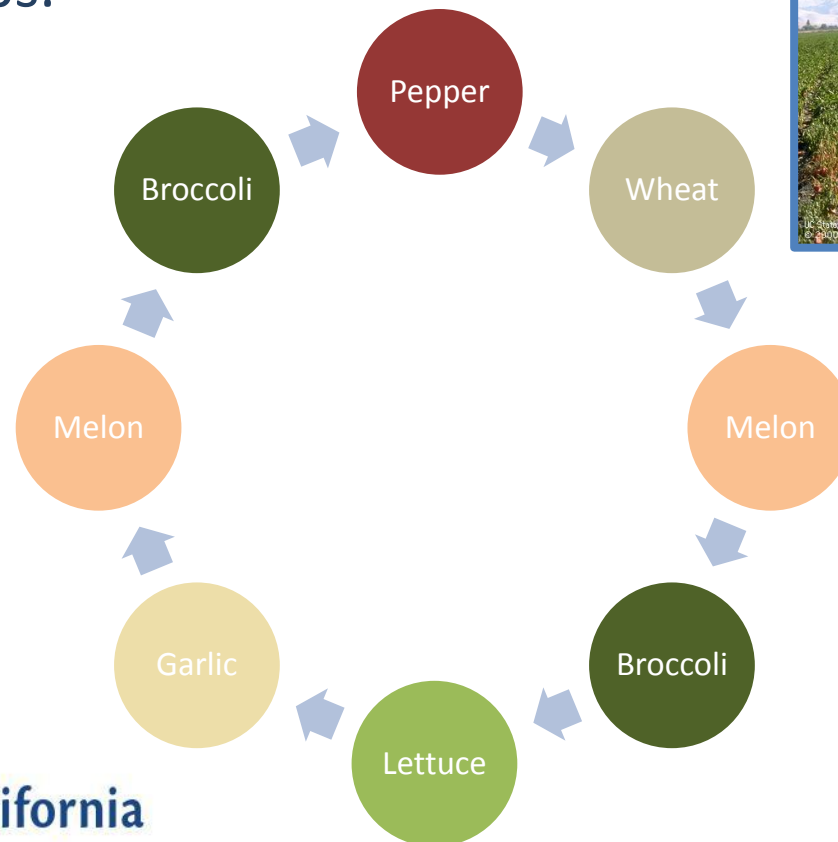


August planted lettuce may be severely damaged by TSWV. Avoid planting near tomatoes with high levels of the virus.

Site/Crop Selection

- Avoid planting susceptible crops near sources of diseases or consider management strategies.
- Rotate crops.

If your objective is to reduce levels of *Phytophthora capsici*, *P. nicotinae* var. *parasitica*, the following rotation would be effective. Note: You must avoid other hosts.



University of California
Agriculture and Natural Resources

Site/Crop Selection

- Avoid planting susceptible crops near sources of diseases or consider management strategies.
- Crop rotation
- Fields infested by extremely long-lived pathogens for which remediation is not economical should be marked and avoided for susceptible crops.

Widespread infestations with *Sclerotium cepivorum* within a field can cause complete crop loss to garlic or onion crops. Effective remediation measures prohibitively costly so the fields are used for non-susceptible crops



University of California
Agriculture and Natural Resources

Variety Selection

- Genetic resistance (through traditional breeding programs) is available to many common diseases. In tomato, “VFFPN SW” indicates resistance to Verticillium Race 1, Fusarium wilt Races 1 & 2, bacterial speck, root knot nematode and TSWV

Variety Selection

- Genetic resistance (through traditional breeding programs) is available to many common diseases. In tomato, “VFFPN SW” indicates resistance to Verticillium Race 1, Fusarium wilt Races 1 & 2, bacterial speck, root knot nematode and TSWV
- Differences in levels of susceptibility to many pathogens exist among varieties without true genetic resistance.



Relative susceptibility of lettuce to downy mildew



Relative susceptibility of melon to Monosporascus vine decline

University of California
Agriculture and Natural Resources

Relative Susceptibility of Processing Tomatoes to TSWV

Genetic resistance (SW5)		Low		Variable or Medium		High	
AB 8058	paste	H 4007	multi use	AB 2	multi use	AB 3	multi use
H 5508	paste	SUN 6368	peel, solids	BQ 205	paste, peel	H 2601	pear
H 5608	paste	UG 4305	multi use	CXD 255	multi use	H 8004	multi use
N 6394	multi use	UG 19406	multi use	CXD 282	multi use	H 8504	paste
N 6385	peel, solids			H 2005	multi use	HM 6898	multi use
				H 9780	multi use	NUN 672	viscosity
				HMX 7885	pear		
				NDM 5578	multi use		
				PX 1723	dice, peel		
				SUN 6366	multi use		

University of California
Agriculture and Natural Resources

Disease-Free Planting Material

Many common pathogens are moved with seed

Carrots		Cole Crops		Cucurbits		Tomato	
<i>Alternaria dauci</i>	Alternaria leaf blight	<i>A. brassicae</i> , <i>A. brassicicola</i>	Alternaria leafspot	<i>Squash mosaic virus</i>		<i>A. Solani</i>	Early blight
<i>A. radicina</i>	Black crown	<i>Pseudomonas syringae</i> pv. <i>maculicola</i>	Bacterial leafspot	<i>Acidovorax avenae</i> subsp. <i>citrulli</i>	Bacterial fruit blotch	<i>Clavibacter michiganensis</i> subsp. <i>michiganensis</i>	Bacterial canker
<i>Cercospora carotae</i>	Cercospora leaf blight	<i>Phoma lingam</i>	Black leg	<i>Fusarium oxysporum</i> f. sp. <i>cucumerinum</i>	Fusarium wilt	<i>P. syringae</i> pv. <i>tomato</i>	Bacterial speck
<i>Xanthomonas campestris</i> pv. <i>carotae</i>	Bacterial leaf blight	<i>Xanthomonas campestris</i> pv. <i>campestris</i>	Black rot			<i>X. Campestris</i> pv. <i>vesicatoria</i>	Bacterial spot

Disease-Free Planting Material

Many common pathogens are moved with seed

Carrots		Cole Crops		Cucurbits		Tomato	
<i>Alternaria dauci</i>	Alternaria leaf blight	<i>A. brassicae</i> , <i>A. brassicicola</i>	Alternaria leafspot	<i>Squash mosaic virus</i>		<i>A. Solani</i>	Early blight
<i>A. radicina</i>	Black crown	<i>Pseudomonas syringae</i> pv. <i>maculicola</i>	Bacterial leafspot	<i>Acidovorax avenae</i> subsp. <i>citrulli</i>	Bacterial fruit blotch	<i>Clavibacter michiganensis</i> subsp. <i>michiganensis</i>	Bacterial canker
<i>Cercospora carotae</i>	Cercospora leaf blight	<i>Phoma lingam</i>	Black leg	<i>Fusarium oxysporum</i> f. sp. <i>cucumerinum</i>	Fusarium wilt	<i>P. syringae</i> pv. <i>tomato</i>	Bacterial speck
<i>Xanthomonas campestris</i> pv. <i>carotae</i>	Bacterial leaf blight	<i>Xanthomonas campestris</i> pv. <i>campestris</i>	Black rot			<i>X. Campestris</i> pv. <i>vesicatoria</i>	Bacterial spot

Many pathogens that may not be common to this area can be introduced with infested seed or infected transplants.

University of California
Agriculture and Natural Resources

Cucurbit yellow stunting disorder virus

Risk of introduction of exotic pests on planting material



University of California
Agriculture and Natural Resources

Tomato yellow leaf curl virus

Risk of introduction of exotic pests on planting material



Photos from Robert Gilbertson

University of California
Agriculture and Natural Resources

Planting Date: Disease Pressure is Frequently Seasonal

- Slow growth and cool conditions favor diseases like corky root of tomato *Rhizoctonia* seedling diseases and black root rot of cotton.



UC Statewide IPM Project
© 2000 Regents, University of California

Corky root of tomato

University of California
Agriculture and Natural Resources

Planting Date: Disease Pressure is Frequently Seasonal

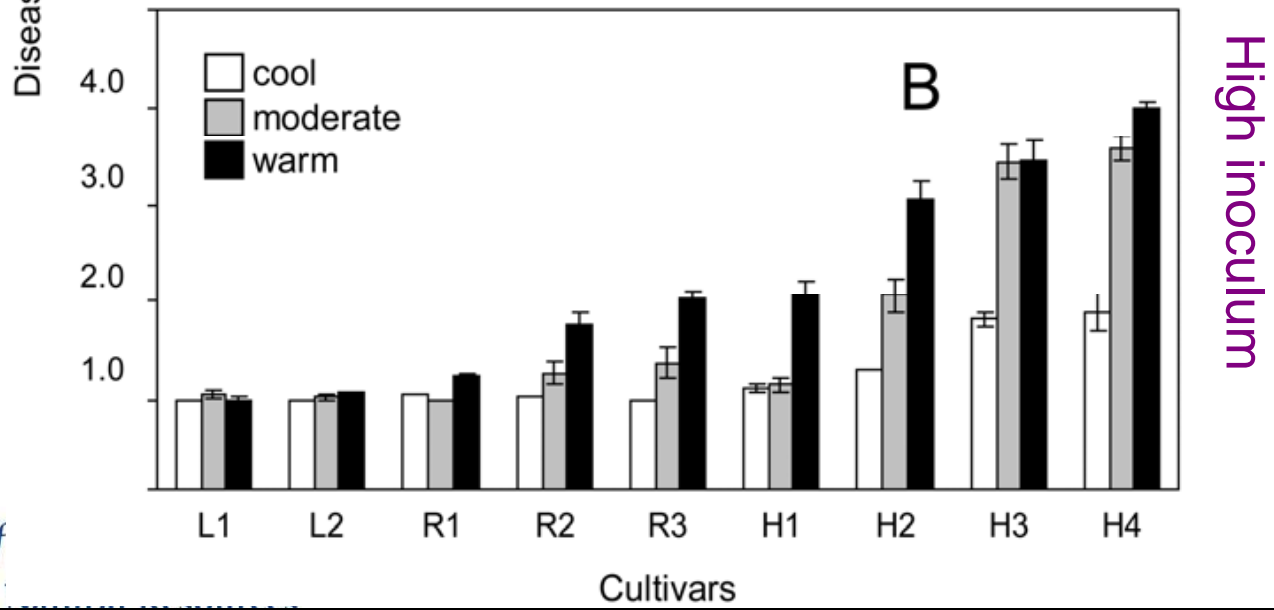
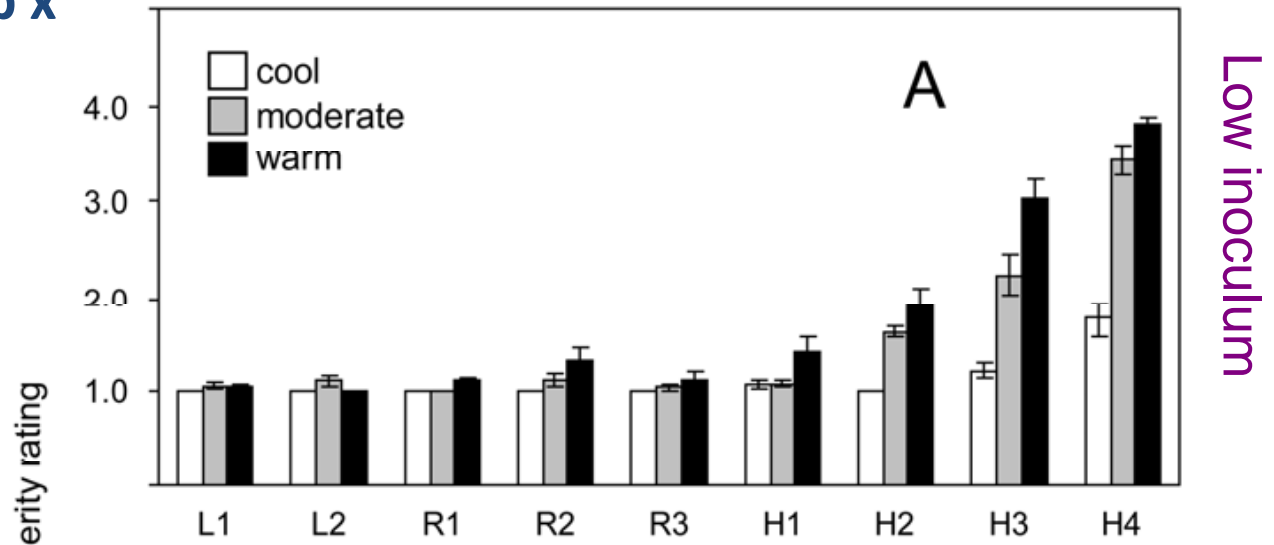
- Slow growth and cool conditions favor diseases like *Rhizoctonia* seedling diseases and black root rot of cotton.
- High soil temperatures favor *Fusarium* wilt development.



University of California
Agriculture and Natural Resources

Variety x Temp x inoculum concentration

- LEAF
 L1 = Lolla Rossa
 L2 = Red Rossa
- ROMAINE
 R1 = King Henry
 R2 = Caesar
 R3 = Green Forest
- HEAD
 H1 = Grand Max
 H2 = Salinas
 H3 = Kahuna
 H4 = Early Queen

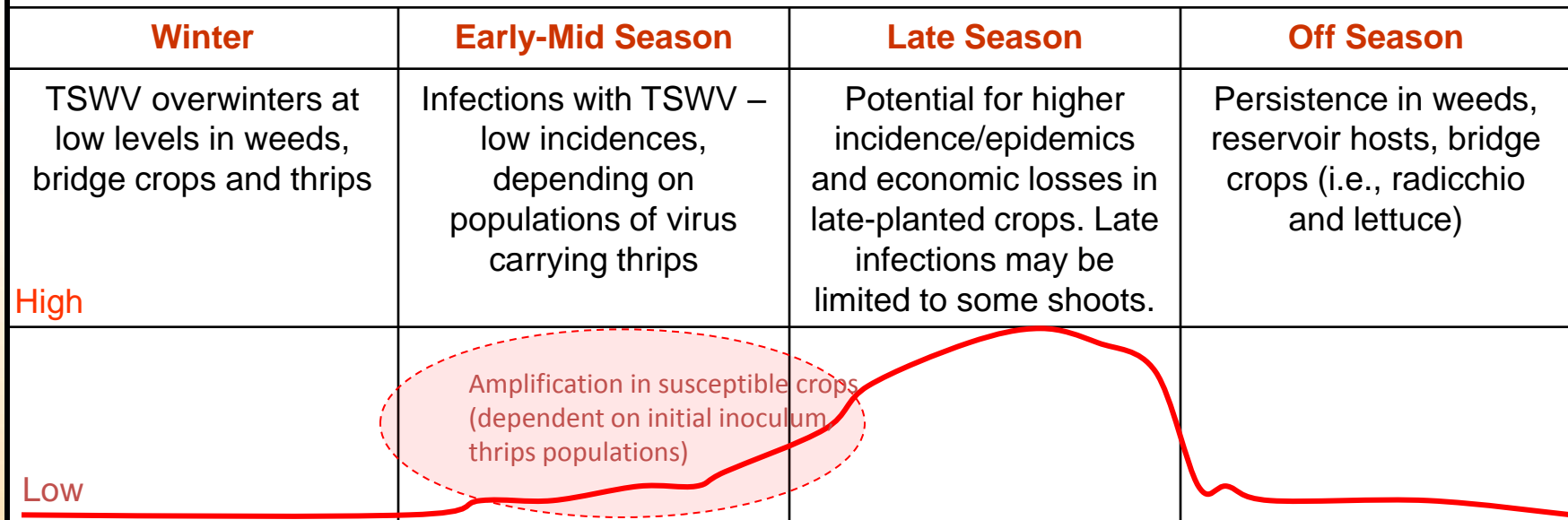


University of
 Agriculture and

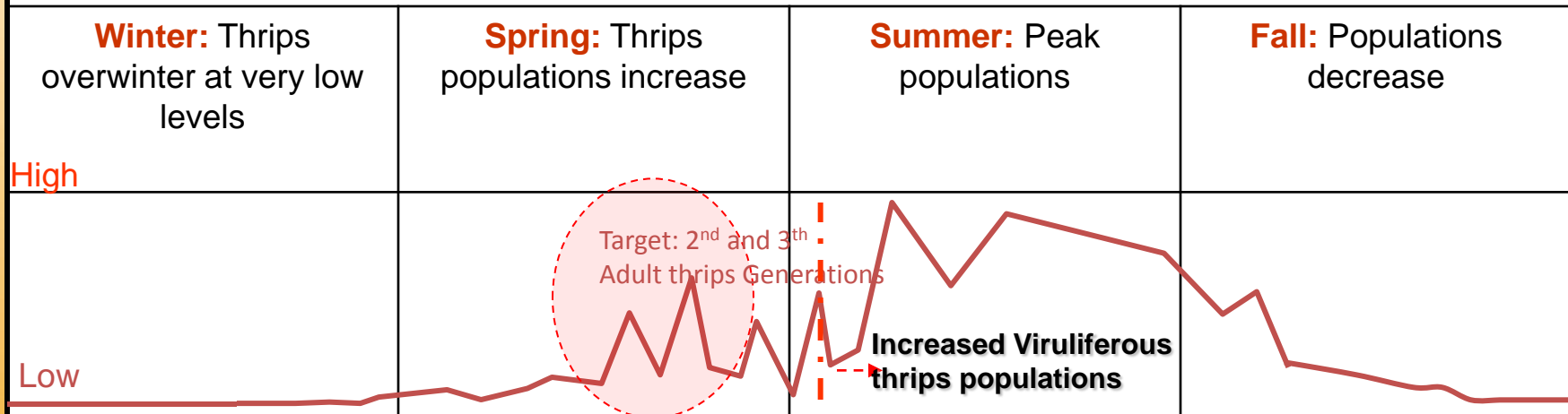
Planting Date: Disease Pressure is Frequently Seasonal

- Slow growth and cool conditions favor diseases like *Rhizoctonia* seedling diseases and black root rot of cotton.
- High soil temperatures favor *Fusarium* wilt development.
- Insect-borne viruses (TSWV) are at lower levels in the environment in early spring than in fall. Late plantings are at higher risk of developing virus symptoms.

Development of TSWV in Processing Tomato Fields



Western Flower Thrips Population Dynamics in the Central Valley of California



December January February March April May June July August September October November

Soil Preparation

- High levels of crop residues can increase chances of Rhizoctonia diseases.
- Deep incorporation can bury inoculum sufficiently to avoid disease
- Deep ripping can increase water penetration and decrease chances of Phytophthora diseases on many crops.

Irrigation

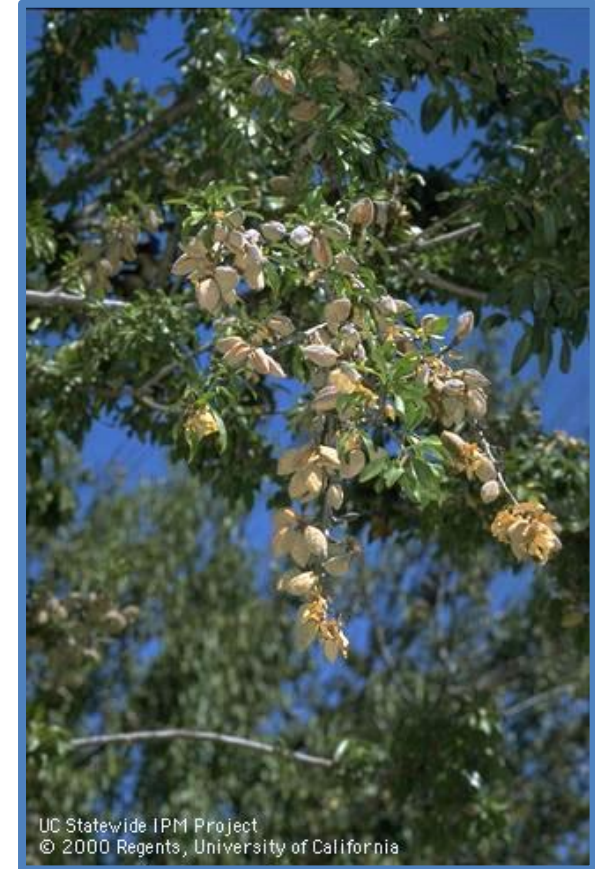
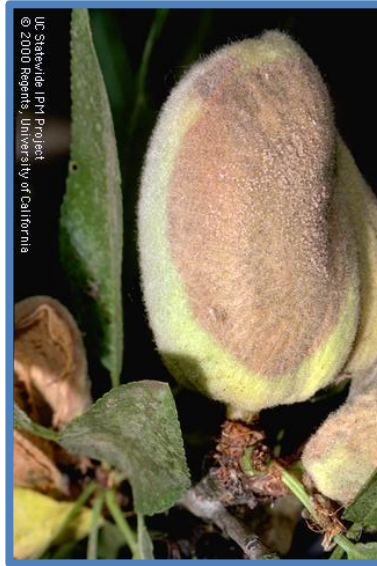
- Avoid irrigation that results in waterlogged soils: *Phytophthora* and *Pythium* are favored by wet conditions.
- Sprinkler irrigation in which foliage is wet, favors many foliar diseases; downy mildew and bacterial diseases of many crops.
- Irrigation while temperatures are high and crop is mature can result in serious losses. Bacterial soft rot development in carrot is an example.

Botrytis neck and bulb rot is favored by late season irrigations.



Irrigation – Use of controlled deficit irrigation to reduce hull rot in almond

Impose enough stress at initiation of hull split to shorten that period, but avoid stress levels that will create mite problems or defoliation.



University of California
Agriculture and Natural Resources

Plant/Canopy Density

- Higher plant density can decrease losses due to Beet curly top virus.
- Lower plant/canopy densities can reduce risk of foliar or fruit diseases favored by wet or humid conditions.



Vine trimming can reduce fruit wetness and black mold in late season tomatoes.

University of California
Agriculture and Natural Resources

Crop Monitoring

- Nutrition maintenance
- Pest pressure documentation
- Disease detection at early onset can be critical



University of California
Agriculture and Natural Resources

Maintenance of Plant Health

- Expression of some diseases is more severe when health of the plant is compromised.
- Avoid mechanical damage to plants if possible. Mechanical damage creates a site at which a pathogen can enter.

Gray Mold (*Botrytis cinerea*) will land on damaged or dead tissue and rapidly colonize that food source. Once established, it will move into healthy tissue.



University of California
Agriculture and Natural Resources

Physical Means of Pest Control

- Removal of infected plants.
- Solarization: heating moist soil to reduce levels of pathogens, nematodes, insects and weeds in the soil.



Trees with almond leaf scorch, a leafhopper transmitted bacterium, should be removed if in or near a young orchard.



Solarization for control of soil-borne pests in a melon field in the low desert.

University of California
Agriculture and Natural Resources

Chemical or Biological Agents for Disease Control

The following list is not comprehensive. In the list, materials are mentioned for which stating that all been found to be efficacious unless stated so in the research results.

Before acquiring these products, check registration with state and organic approval with certifier. Specific directions on the fungicide labels must be adhered to.

The following list of materials are listed in an online publication:

McGrath, M. T. 2010. Efficacy of various microbial and biological fungicides – Does that really work? Extension Plant Pathology, Cornell.
http://www.newenglandvfc.org/pdf_proceedings/2009/EVBMI-DTRW2.pdf

University of California
Agriculture and Natural Resources

Chemical or Biological Agents for Disease Control:

Trade name, composition, registered use

Actinovate SP (0.0371% *Streptomyces lydicus*) foliar and soil-borne diseases

Cease (1.34% *Bacillus subtilis* QST 713 strain) diseases in greenhouses

Companion (0.03% *Bacillus subtilis* GB03) foliar diseases on many crops

Contans WG (5.3% *Coniothyrium minitans* strain CON/M/91-08)

Sclerotinia sclerotiorum and *S. minor* on several crops.

Copper fungicides/bactericides. OMRI listed products include Champ WG, Nordox 75WG and NuCop HB. Bacterial and fungal diseases on many crops.

JMS Stylet-oil. (97.1% Paraffinic oil) For fungal diseases, aphid transmitted viruses on several crops.

Kaligreen. (82% potassium bicarbonate) Powdery mildew on many crops.

KeyPlex 350 OR (alpha-keto acids, defensive proteins, and secondary and micronutrients) SAR against bacterial and fungal diseases.

Mildew Cure, formerly GC-3 Organic fungicide, (30% cottonseed oil, 30% corn oil, 23% garlic extract) powdery mildew on various crops

University of California

Agriculture and Natural Resources

Chemical or Biological Agents for Disease Control:

Trade name, composition, registered use

MilStop. (85% potassium bicarbonate) Powdery mildew and several other diseases on many crops.

Organocide (5% sesame oil) several fungal diseases and insects

Oxidate (27% hydrogen dioxide) Several diseases on many crops

Promax (3.5% thyme oil) Soil borne fungal diseases and nematodes on many crops.

Proud-3 (5.6% thyme oil) broad spectrum fungicide, insecticide and miticide

Regalia SC (5% extract of *Reynoutria sachalinensis*) Against several fungal and bacterial diseases on several crops

Saf-T-Side (80% petroleum oil) Insecticide and miticide on vegetable crops and for powdery mildew and rust on other crops

Serenade Max (14.6% *Bacillus subtilis* strain QST 713) Many diseases on many crops

Sonata (1.38% *Bacillus pumilus* strain QST 2808) Several diseases on many crops.

University of California

Agriculture and Natural Resources

Chemical or Biological Agents for Disease Control:

Trade name, composition, registered use

Sporatec AG (18% rosemary oil, 10%, clove oil and 10% thyme oil) Several bacterial and fungal diseases on many crops

Sulfur fungicides OMRI listed products include Microthiol Disperss, THAT Flowable Sulfur and Yellow Jacket Sulfur 80DF. Powdery mildew and mites on several crops.

T-22 HC, formerly Plant Shield HC. (1.15% *Trichoderma harzianum* Rifai strain KRL-AG2) Protects plant roots against fungal pathogens. Apply to seed, transplants or soil mix.

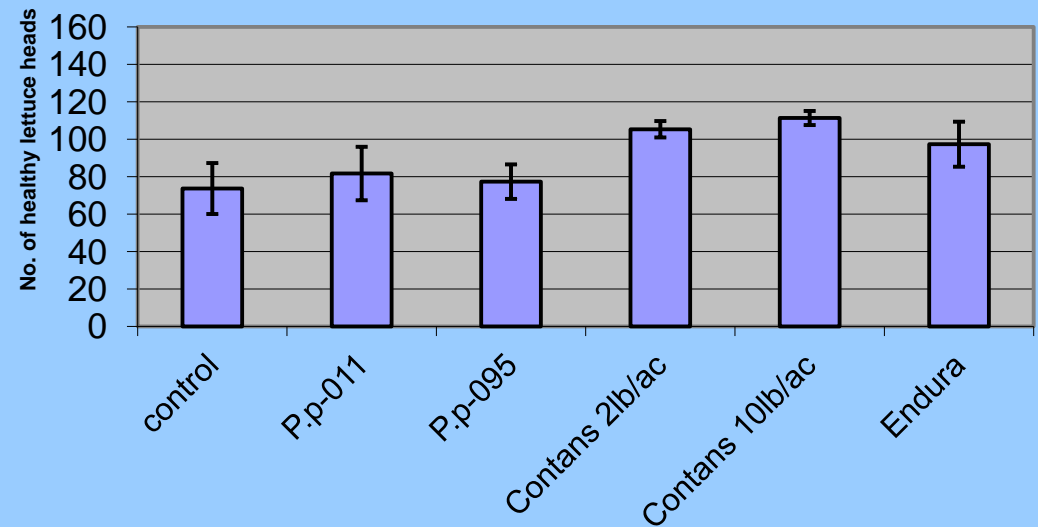
Trilogy (70% clarified hydrophobic extract of neem oil) Several diseases of several crops.

Yield Shield (0.28% *Bacillus pumilus* GB34) Seed treatment labeled for *Rizoctonia* and *Fusarium* and other root pathogens on several crops.

Chemical or Biological Agents for Disease Control

- Contans provided good control of soil-borne *Sclerotinia sclerotiorum* in studies conducted at the UC Desert Research and Extension Center.

Contans applied at 2 lbs/a increased number of healthy heads by 44%.



Contans is consistently effective only
against *S. sclerotiorum*



Sclerotinia minor



S. sclerotiorum

University of California
Agriculture and Natural Resources

S. sclerotiorum apothecia and airborne spores



University of California
Agriculture and Natural Resources

From H. R. Dillard, 2004.

Other Materials with Demonstrated Efficacy

Alternaria leaf blight and Cercospora leaf spot: Sporan provided limited control

Downy mildew of cucurbits: SoratecAG, Organocide and NuCop HB, Actinovate, Regalia SC, Serenade MAX, Sonata ASO performed in at least one trial.

Powdery mildew of cucurbits: Microthiol Disperss and Organocide were among the most effective . However, many had activity including coper, Actinovate, Companion, Eco E-Race, Kaligreen, Milstop, Organocide, Regalia, Serenade MAX and Sonata ASO.

Downy mildew of lettuce: Oxidate provided limited control in 1 experiment

Bacterial spot of tomato: Regalia

Powdery mildew of tomato: Sulfur, Actinovate, Regalia, Companion, Sporan, Organocide and Copper

From McGrath online publication

University of California
Agriculture and Natural Resources

Integration into a Program

- Sanitation
- Site/crop selection
- Variety selection
- Disease free planting material
- Planting date
- Soil preparation
- Irrigation
- Plant/canopy density
- Monitoring
- Maintenance of plant health
- Physical means of pest control
- Chemical or biological agents for disease control

Integrated Program for High Risk Pests

Example: IPM for Tomato spotted wilt virus in processing tomatoes

University of California
Agriculture and Natural Resources

HEALTHY FOOD SYSTEMS • HEALTHY ENVIRONMENTS • HEALTHY COMMUNITIES • HEALTHY CALIFORNIANS

IPM for thrips and TSWV

Before planting

- Varietal selection
- Plant TSWV resistant varieties (with *Sw-5* gene) especially in hot-spot areas or late-planted fields Varieties without the *Sw-5* gene vary in susceptibility
- Plant TSWV- and thrips-free transplants



University of California
Agriculture and Natural Resources

From R. L. Gilbertson, 2011

IPM for thrips and TSWV

- **During the season**

- **Field placement** (avoid planting near established fields of susceptible crops with confirmed TSWV infection)
- **Monitor fields for thrips** (yellow sticky cards) and TSWV
- **Manage thrips with insecticides ENTRUST** at early stages of crop development when thrips populations begin to increase
- **Removal of TSWV-infected plants early** (seedling infection) and when percent infection is low (<5%)
- **Weed control in and around fields**



University of California
Agriculture and Natural Resources

From R. L. Gilbertson, 2011

Integrated TSWV Management

- **After harvest**

- **Promptly remove and destroy plants after harvest**
- **Avoid 'bridge' crops that are TSWV/thrips reservoirs and overlap with tomato/pepper (e.g., radicchio, lettuce, fava bean)**
- **Control weeds/volunteers in fallow fields, non-cropped, or idle land near next year's tomato fields**



Thank you



Tom Turini
UC ANR Advisor
Vegetable Crops, Fresno County
taturini@ucdavis.edu
559-375-3147

University of California
Agriculture and Natural Resources

HEALTHY FOOD SYSTEMS • HEALTHY ENVIRONMENTS • HEALTHY COMMUNITIES • HEALTHY CALIFORNIANS